Hyndland Secondary

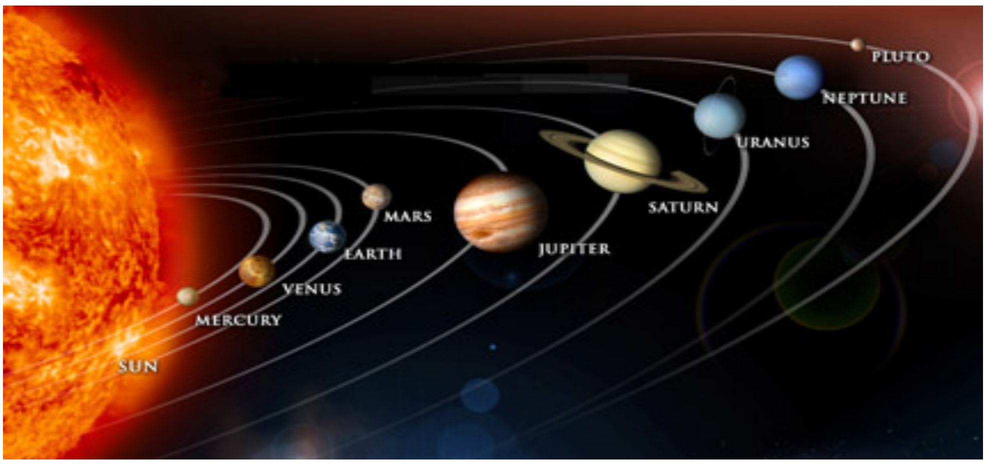
Physics Department

S4

Dynamics and Space

National 4 and National 5

Pupil Booklet



Data Sheet

Speed of light in materials	
Material	*Speed in ms^{-1}*
Air	3×10^8
Carbon dioxide	3×10^8
Diamond	$1{\cdot}2 \times 10^8$
Glass	$2{\cdot}0 \times 10^8$
Glycerol	2.1×10^8
Water	$2{\cdot}3 \times 10^8$

Gravitational field strengths	
	Gravitational field strength on the surface in Nkg^{-1}
Earth	9.8
Jupiter	26
Mars	4
Mercury	4
Moon	1·6
Neptune	12
Saturn	11
Sun	270
Venus	9
Uranus	11·7
Pluto	4·2

Specific latent heat of fusion of materials	
Material	*Specific latent heat of fusion in Jkg^{-1}*
Alcohol	$0{\cdot}99 \times 10^5$
Aluminium	$3{\cdot}95 \times 10^5$
Carbon dioxide	$1{\cdot}80 \times 10^5$
Copper	$2{\cdot}05 \times 10^5$
Glycerol	$1{\cdot}81 \times 10^5$
Lead	$0{\cdot}25 \times 10^5$
Water	$3{\cdot}34 \times 10^5$

Specific latent heat of vaporisation of materials	
|*Material*	*Sp.l.ht vap(Jkg^{-1})*
Alcohol	$11{\cdot}2 \times 10^5$
Carbon dioxide	$3{\cdot}77 \times 10^5$
Glycerol	$8{\cdot}30 \times 10^5$
Turpentine	$2{\cdot}90 \times 10^5$
Water	$22{\cdot}6 \times 10^5$

Speed of sound in materials	
Material	*Speed in ms^{-1}*
Aluminium	5 200
Air	340
Bone	4 100
Carbon dioxide	270
Glycerol	1 900
Muscle	1 600
Steel	5 200
Tissue	1 500
Water	1 500

Specific heat capacity of materials	
Material	*Specific heat capacity in $J\ k^{-1}\,{}^{o}C^{-1}$*
Alcohol	2 350
Aluminium	902
Copper	386
Glass	500
Glycerol	2 400
Ice	2 100
Lead	128
Silica	1 033
Water	4 180
Steel	500

Melting and boiling points of materials		
Material	*Melting point in ${}^{o}C$*	*Boiling point in ${}^{o}C$*
Alcohol	-98	65
Aluminium	660	2470
Copper	1 077	2 567
Glycerol	18	290
Lead	328	1 737
Turpentine	-10	156

SI Prefixes and Multiplication Factors		
Prefix	*Symbol*	*Factor*
giga	G	1 000 000 000 $=10^9$
mega	M	1 000 000 $=10^6$
kilo	k	1 000 $=10^3$
milli	m	0·001 $=10^{-3}$
micro	μ	0·000 001 $=10^{-6}$
nano	n	0·000 000 001 $=10^{-9}$

Vectors and Scalars

National 5

1. Describe what is meant by a scalar quantity.

2. Describe what is meant by a vector quantity.

3. Read the following descriptions of some quantities used in Physics:

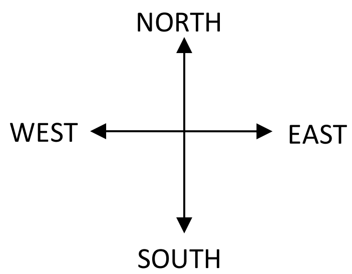
> **Distance** travelled by an object is the total length covered during a journey. Direction is irrelevant.
>
> **Velocity** is the speed of an object in a specified direction.
>
> **Acceleration** tells us how much the velocity of an object changes each second. Because it is about a change in velocity, then direction is important.
>
> **Energy** tells us about an object's ability to do work. Direction is not important.
>
> **Speed** is the distance covered in a specified time. As direction is not relevant for defining distance and time, so it is not relevant in defining speed.
>
> **Displacement** is the change in position of an object specified by a distance *and* a corresponding direction.

(a) Which of the quantities underlined in bold are scalar quantities.
Explain your answer.

(b) Which of the quantities underlined in bold are vector quantities.
Explain your answer.

Distance and Displacement

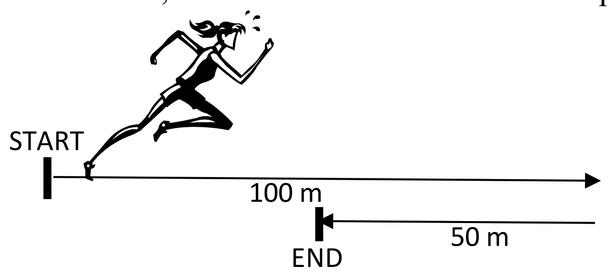
National 5



1. A boy walks 50 m, East then runs for 100 m in the same direction.

(a) State the distance travelled by the boy.
(b) State the final displacement of the boy from the start point. (Remember to give a direction!)

2. A girl runs 100 m, East then walks for 50 m in the opposite direction.

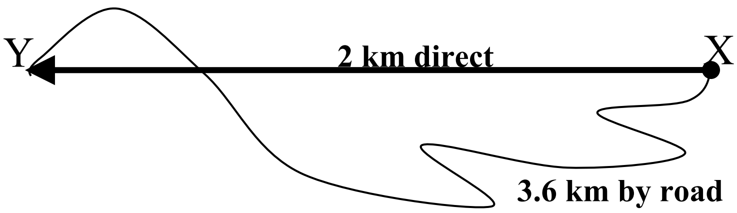


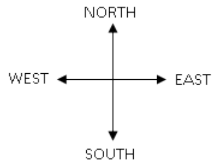
(a) State the distance travelled by the girl.
(b) State the final displacement of the girl from the start point. (Remember to give a direction!)

3. A delivery lorry travels 80 km, North then travels South for 100 km.
(a) State the distance travelled by the lorry.
(b) State the final displacement of the lorry for this journey.

4. During a hike, a hillwalker walks 60 m, South then backtracks 20 m, North.
(a) State the distance covered by the hillwalker.
(b) State the displacement of the hillwalker for this stage of the hike.

5. A girl walks from X to Y along a winding road as shown below.



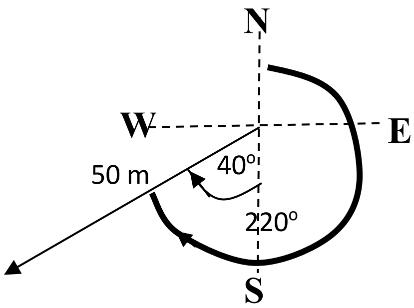


(a) State the distance travelled by the girl.

(b) State the displacement of the girl at Y, from X.

6. Displacement directions can be described using an angle with compass points <u>OR</u> using a three figure bearing; where the angle is clockwise from the North line.

<u>For example</u>



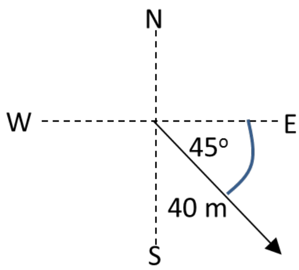
this displacement is
"<u>50m @ 40° W of S</u> "

OR

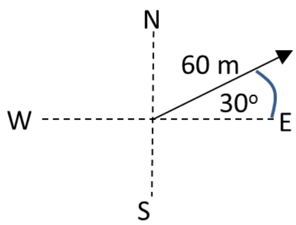
"<u>50m @ 220°</u>"

Describe each of the following displacements using appropriate compass points <u>and</u> with a three figure bearing.

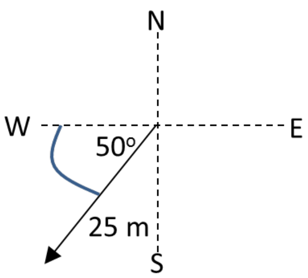
(a)



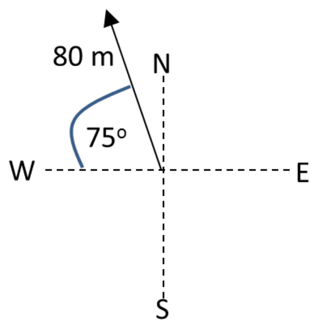
(b)



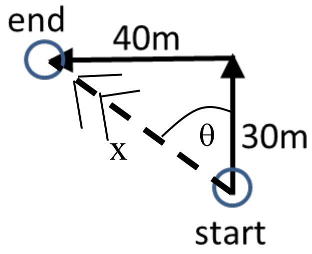
(c)



(d)



7. During an orienteering exercise, a boy walks 30 m, North then 40 m, West.



(a) State the distance travelled during this exercise.

(b) Draw a scale diagram and use it to calculate the magnitude of the boy's displacement, x.

(c) From your scale diagram, measure the direction, θ , of this displacement.

(d) Give this angle as a three figure bearing.

8. A man walks 500 m, due North then 1200 m due West.

(a) State the distance travelled by the man.

(b) Use scale drawing, or otherwise, to determine the final displacement of the man from his starting point.

9. A surveyor walks once around the perimeter of a rectangular field, measuring 80 m by 150 m, returning to his starting point.

(a) State the distance covered by the surveyor.

(b) What is the displacement of the surveyor when he returns to his starting point.

10. A yacht sails 5 km due West followed by 3 km, North.

(a) State the distance travelled by the yacht.

(b) Calculate the final displacement of the yacht from its starting point.

11. A car travels 8 km, East followed by 8 km, South.

(a) State the distance travelled by the car.

(b) Calculate the final displacement of the car from its starting point.

12. A cyclist cycles 5 km, North, then 4 km, West followed by 8 km, South.

(a) State the distance travelled by the cyclist.

(b) Calculate the displacement of the cyclist for this journey.

Speed and Velocity

National 5

In this section you can use the equations:

$$\text{speed} = \frac{\text{distance}}{\text{time}} \quad \text{AND} \quad \text{velocity} = \frac{\text{displacement}}{\text{time}}$$

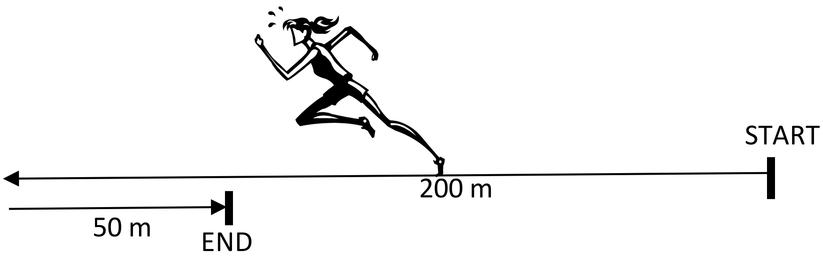
also written as

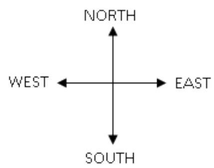
$$\text{speed} = \frac{d}{t} \qquad v = \frac{s}{t}$$

Where **d** = distance in metres (m)
v = velocity in metres per second (ms^{-1})
s = displacement in metres (m)
t = time in seconds (s)
speed is in metres per second (ms^{-1})

1. One lap of a running track is 400 m. An athlete completes this lap in 48 s.
   (a) State the distance travelled by the athlete.
   (b) State the displacement of the athlete.
   (c) Calculate the average speed of the athlete.
   (d) Calculate the average velocity of the athlete.

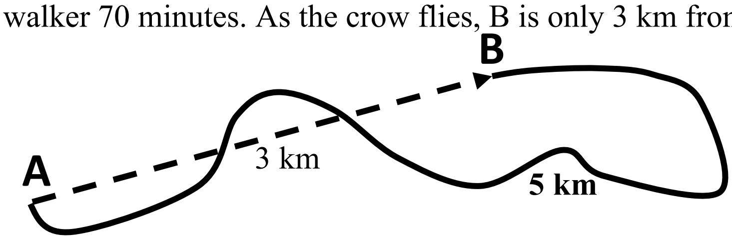
2. A girl runs 200 m, West then walks 50 m East. It takes her 50 seconds to do this.





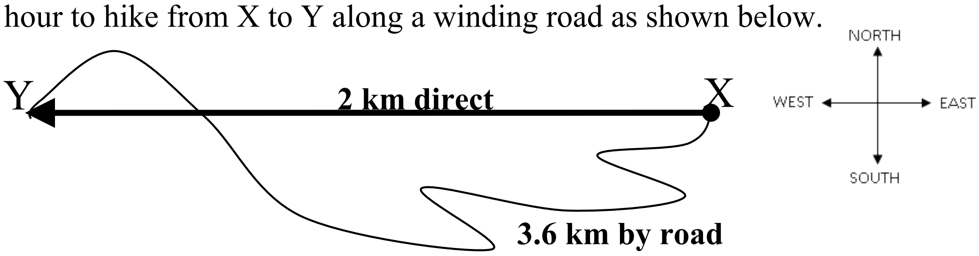
   (a) State the distance travelled by the girl.
   (b) State the overall displacement of the girl.
   (c) Calculate the girl's average speed.
   (d) Calculate the girl's average velocity.

3. A walker travels from A to B along a winding path as shown below. The 5 km walk takes the walker 70 minutes. As the crow flies, B is only 3 km from A, at 085°.



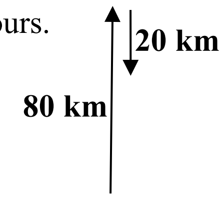
   (a) Calculate the average speed of the walker in ms^{-1}.
   (b) Calculate the average velocity of the walker in ms^{-1}.

4. A girl takes 1 hour to hike from X to Y along a winding road as shown below.

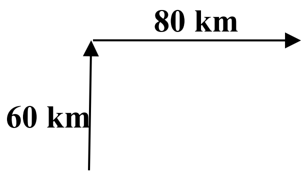


(a) Calculate the average speed of the girl in km h^{-1}.
(b) Calculate the average velocity of the girl in km h^{-1}.

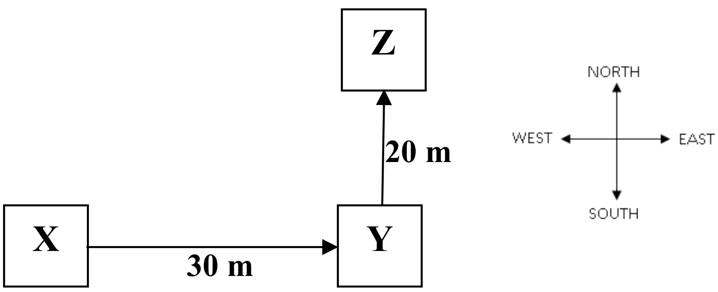
5. A car travels 80 km, North, then 20 km, South. The journey takes 2 hours.
(a) State the distance travelled by the car.
(b) State the overall displacement of the car in this time.
(c) Calculate the car's average speed in km h^{-1}.
(d) Calculate the car's average velocity in km h^{-1}.



6. A lorry travels 60 km, North, then 80 km, East, as shown here.
The journey takes 2 hours.
(a) State the distance travelled by the lorry.
(b) Calculate the overall displacement of the lorry.
(c) Calculate the lorry's average speed in km h^{-1}.
(d) Calculate the lorry's average velocity in km h^{-1}.



7. A boy delivers newspapers to three houses; X, Y and Z, as shown in the diagram below. It takes him 1 minute to reach house Z from house X.



(a) State the distance covered by the boy.
(b) When he reaches house Z, what is the boy's displacement from house X?
(c) Calculate the average speed of the boy between houses X and Y.
(d) Calculate the average velocity of the boy between houses X and Y.

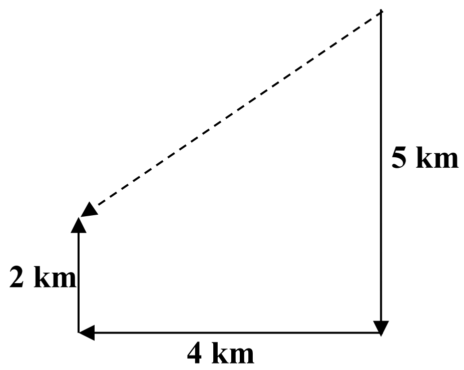
8. A cyclist cycles 500 m, West, followed by 600 m, South, in 110 seconds.
   (a) State the distance travelled by the cyclist.
   (b) Calculate the overall displacement of the cyclist for the 110 s period.
   (c) Calculate the average speed of the cyclist.
   (d) Calculate the cyclist's average velocity.

9. During a section of a yacht race, a yacht sails 800 m, East, followed by 400 m, North, with a steady speed of 12 ms^{-1}.
   (a) State the distance travelled by the yacht.
   (b) Calculate the displacement of the yacht for this section of the race.
   (c) Calculate the time taken for the yacht to complete this section of the race.
   (d) Calculate the average velocity of the yacht.

10. A tortoise moves 5 m, South, followed by 3 m, East, with a steady speed of 0.2 ms^{-1}.
   (a) State the distance travelled by the tortoise.
   (b) Calculate the displacement of the tortoise from its start point.
   (c) Calculate the time taken for the tortoise to do this.
   (d) Calculate the average velocity of the tortoise.

11. A robot moves 6 m, North, followed by 6 m, East, at a steady speed of 2 ms^{-1}.
   (a) State the distance travelled by the robot.
   (b) Calculate the displacement of the robot from his start point.
   (c) Calculate the time taken for the robot to complete these moves.
   (d) Calculate the average velocity of the robot.

12. An orienteer runs 5 km , South, followed by 4 km, West, followed by 2 km, North, in 3 hours.



   (a) State the distance travelled by the orienteer.
   (b) Calculate the overall displacement of the orienteer.
   (c) Calculate the orienteer's average speed in km h^{-1}.
   (d) Calculate the orienteer's average velocity in km h^{-1}.

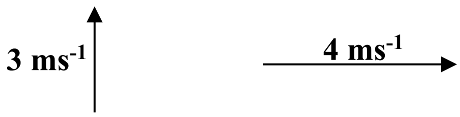
Combining Velocities

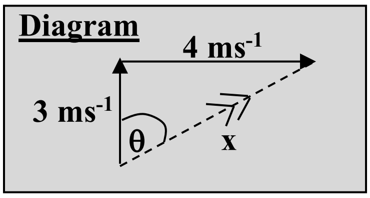
National 5

1. For each of the following combinations of velocities, draw a diagram to represent the velocities involved and the resultant velocity. **Remember to draw the given velocities NOSE TO TAIL.** The first diagram is drawn for you.

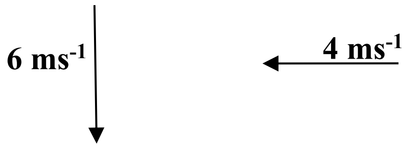
   "**x**" is the magnitude of the resultant velocity.
   "**θ**" is the direction of the resultant velocity, usually given as a three figure bearing.

   (a) 3 ms^{-1}, North and 4 ms^{-1}, East.

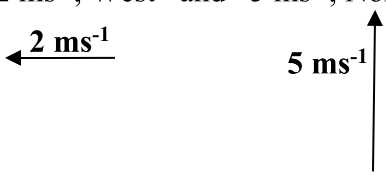




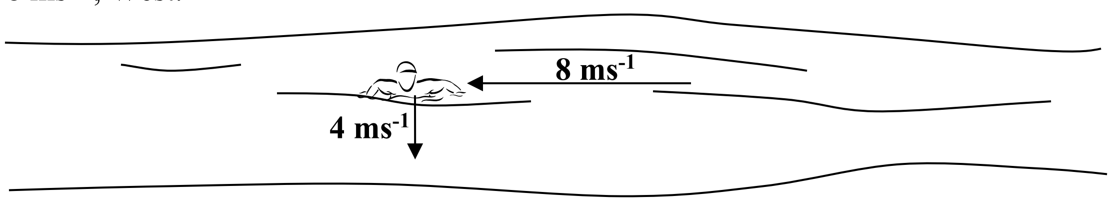
   (b) 6 ms^{-1}, South and 4 ms^{-1}, West.



   (c) 2 ms^{-1}, West and 5 ms^{-1}, North.



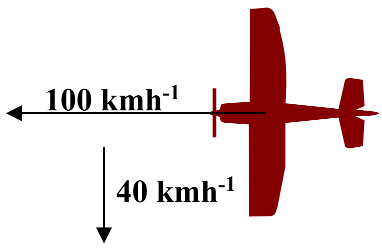
2. A boy aims to swim South across a river with a velocity of 4 ms^{-1}. The river's velocity is 8 ms^{-1} , West.



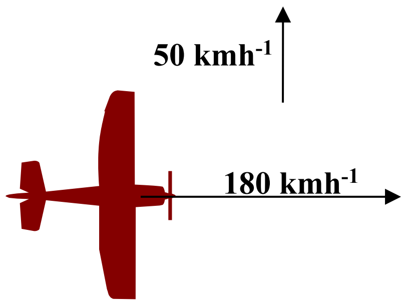
   Calculate the resultant velocity of the boy.

3. A girl aims to swim North across a river with a velocity of 3 ms^{-1}. This river's velocity is 6 ms^{-1}, East.
   Calculate the resultant velocity of the girl.

4. A pilot selects a course of 100 kmh^{-1} due West.
   A wind is blowing with a velocity of 40 kmh^{-1}, due South.
   Calculate the resultant velocity of the plane.



5. A pilot selects a course of 180 kmh^{-1}, due East.
A wind is blowing with a velocity of 50 kmh^{-1}, due North.



(a) Show that the resultant velocity of the plane is 187 kmh^{-1} at 16° North of East.

(b) Use your answer to part (a) to suggest what course the pilot *should* select to make sure he ends up moving at 180 kmh^{-1} due East in this wind.

6. An aeroplane is flying with its course set at 1000 kmh^{-1}, North.
It is flying into a wind which has a velocity of 100 kmh^{-1}, South.
Calculate the resultant velocity of the aeroplane.

7. An aircraft pilot sets a course for 800 kmh^{-1}, North.
A wind is blowing at 80 kmh^{-1} from West to East.

(a) Calculate the resultant velocity of the plane. (You should sketch a suitable diagram first.)

(b) Use your answer to part (a) to suggest what course the pilot *should* select so that the plane does fly at 800 kmh^{-1} due North.

8. A model aircraft is flying North at 24 ms^{-1}.
A wind is blowing from West to East at 10 ms^{-1}.
Draw a suitable diagram and use it to calculate the resultant velocity of the model aircraft.

9. A ship is sailing East at 4 ms^{-1}on calm waters.
A passenger on the deck walks at 2 ms^{-1}due North.
Draw a suitable diagram and use it to calculate the resultant velocity of the passenger.

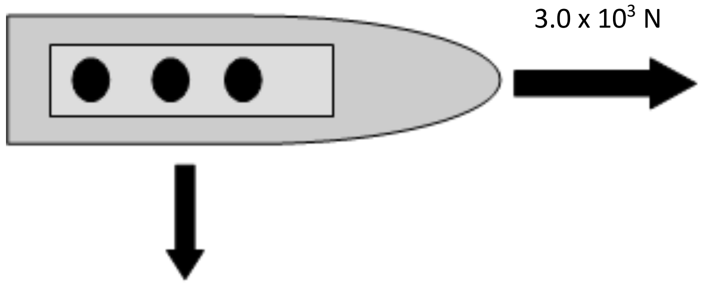
10. On still water, a remote controlled toy boat moves at 3.6 ms^{-1}.
The boat is set to move West across a river but the river is flowing at 4.8 ms^{-1} North.

Calculate the resultant velocity of the boat.

Combining Forces

National 5

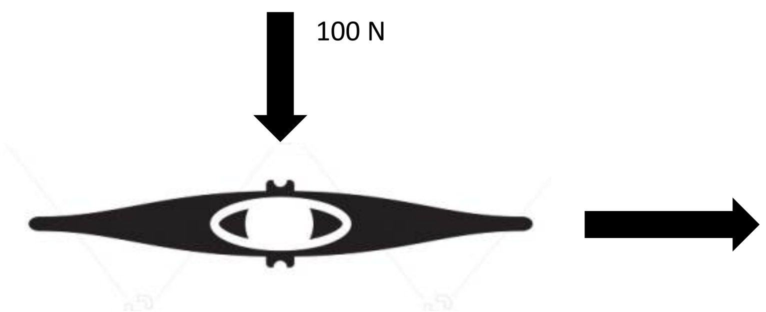
1. A tug boat is sailing due East along a river with an engine force of 3.0×10^3 N. It experiences a tidal force of 2.1×10^3 N South as shown in the diagram below.



(a) Find the resultant force acting on the boat.

(b) Find the acceleration of the boat which has a mass of 15×10^3 kg.

2. During a kayak race, a kayaker provides a forward force of 500 N. A cross breeze during the race provides a force of 100N at right angles to the direction of the race as shown.

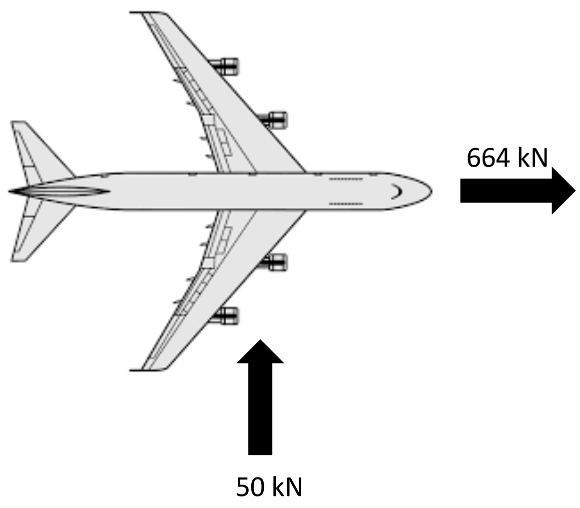


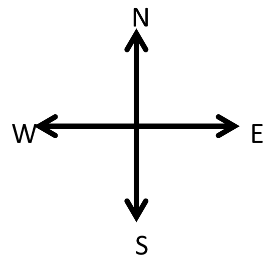
Calculate:

(a) the magnitude of the resultant force.

(b) the direction of the resultant force relative to the 500N force.

3. During a flight, the engines of a Boeing-747 produce a force of 664 kN. The plane encounters a side breeze of 50 kN as shown in the diagram below.





(a) Find the resultant force acting on the aircraft.

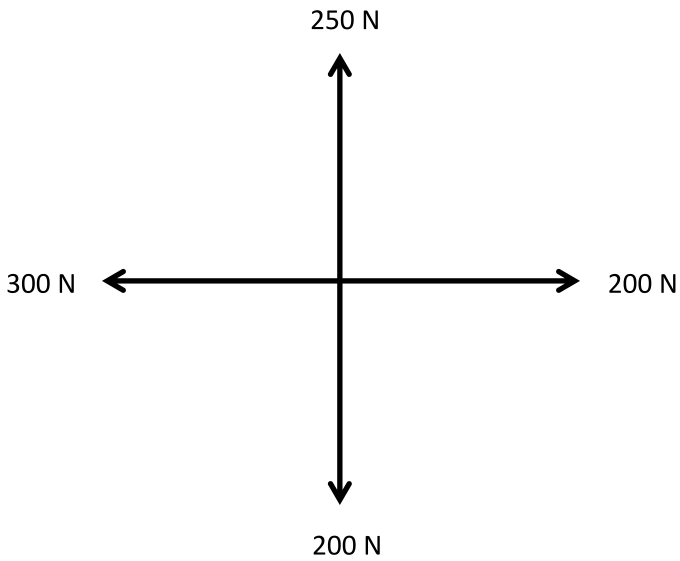
(b) If the plane has a mass of 4.13×10^5 kg find the acceleration of the aircraft.

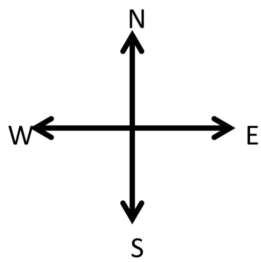
(c) A typical cruising altitude for a plane is 11.9 km. At this altitude, the strength of the Earth's gravitational field is 9.76 Nkg^{-1}. Calculate the weight of the aircraft at this height.

(d) State the lift (upwards force) required to glide the plane at a constant height.

4. Tug of war is a traditional test of strength.

During a four person tug of war event, the following forces were exerted on the rope.

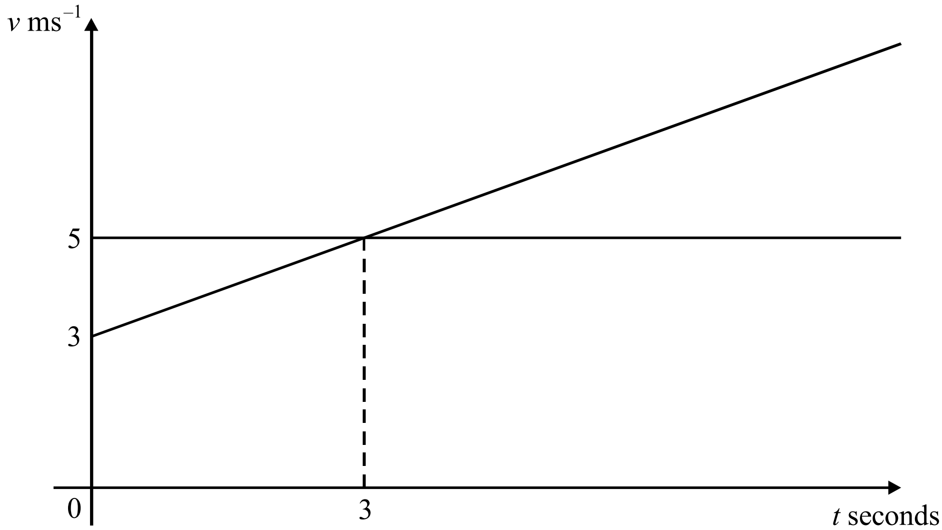




Calculate the magnitude and direction of the resultant force acting on the rope.

Velocity-Time Graphs

1. The graph below shows the motion of a car and a bicycle along a straight horizontal road. When $t = 0$, they pass a traffic light with the bicycle travelling with a constant velocity of $5\ \text{m s}^{-1}$, but the car travelling at $3\ \text{m s}^{-1}$ and accelerating.

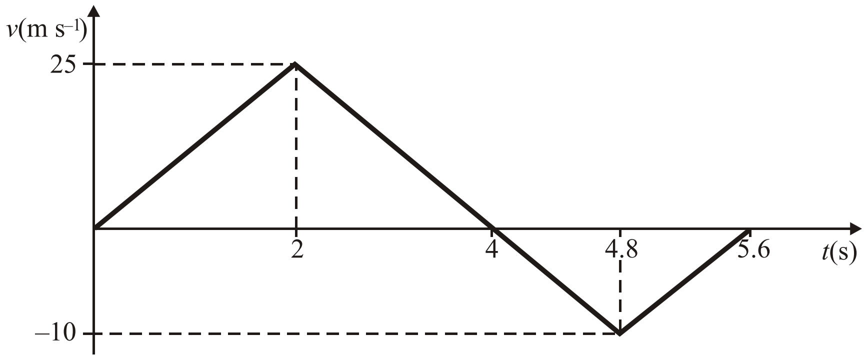


(a) (i) Explain how the graph indicates that the acceleration of the car is constant.

(ii) Find the acceleration of the car.

(b) Find how far ahead of the car the bicycle is after 3s.

2. A student attempts to model the motion of a bungee jumper falling from a 60 m height. He draws the velocity–time graph shown below.



(a) State the two non-zero times at which the velocity of the bungee jumper is zero.

(b) Find the distance that the bungee jumper falls during the first 4 seconds.

(c) Find the height of the bungee jumper above the ground after 4 seconds.

(d) Find the height of the bungee jumper above the ground after 5.6 seconds.

(e) Find the acceleration of the bungee jumper during the first 2 seconds and hence state one problem with the proposed model.

Projectiles

National 5

Helpful Hint

In this section you should remember that the motion of a projectile should be dealt with in separate calculations for its horizontal and vertical paths.

Horizontally Velocity is constant. ($a = 0\ ms^{-2}$)

$$\bar{v} = \frac{d}{t}$$

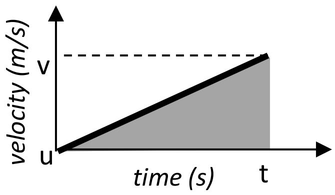
where $\bar{v}$ = average horizontal velocity in metres per second (ms^{-1})
d = horizontal distance travelled in metres (m)
t = time taken in seconds (s).

Vertically Acceleration is downwards due to gravity. (a = approx $10\ ms^{-2}$ on Earth)

$$a = \frac{v - u}{t}$$

where **u** = initial vertical velocity in metres per second (ms^{-1})
v = final vertical velocity in metres per second (ms^{-1})
a = acceleration due to gravity in metres per second per second (ms^{-2})
t = time taken in seconds (s).

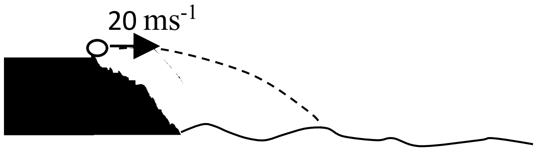
To calculate the vertical displacement (height) during any projectile journey you must draw a velocity - time graph for the journey and use:



Height = area under velocity - time graph
= ½ x base x height

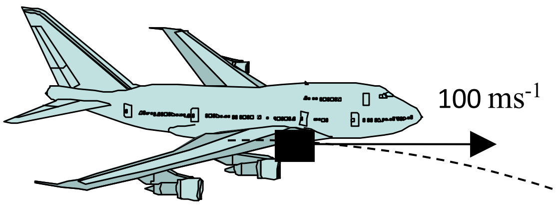
= ½ x t x (v-u)

1. A stone is kicked horizontally at 20 ms^{-1} from a cliff top and lands in the water below 2 seconds later.



Calculate :
(a) the **horizontal** distance travelled by the stone
(b) the final **vertical** velocity
(c) the vertical height through which the stone drops.

2. A parcel is dropped from a plane and follows a projectile path as shown below. The horizontal velocity of the plane is 100 ms^{-1} and the parcel takes 12 seconds to reach the ground.

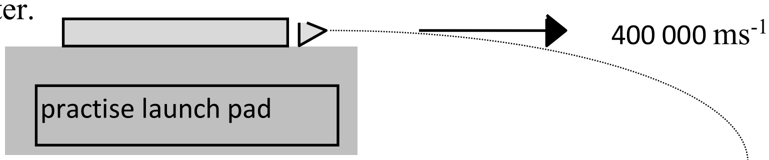


Calculate :
(a) the **horizontal** distance travelled by the parcel
(b) the final **vertical** velocity of the parcel as it hits the ground
(c) the height from which the parcel was dropped.

3. Sand bags are released from a hot air balloon while it is moving horizontally at 30 ms^{-1}. The sand bags land on the ground 10 seconds after they are released.

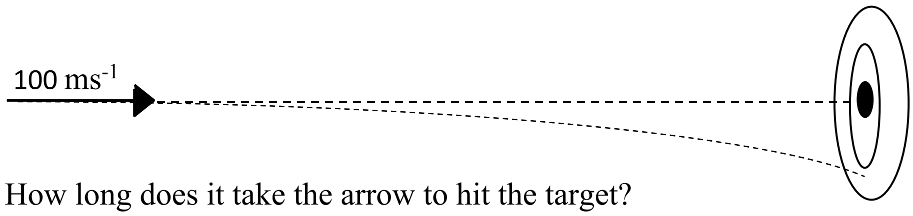
Calculate:
(a) the **horizontal** distance travelled by the sand bags
(b) their final **vertical** velocity.

4. A satellite is launched during a practice simulation. The satellite is given a horizontal velocity of 400 000 ms^{-1} and ‘crashes’ 200 seconds later.



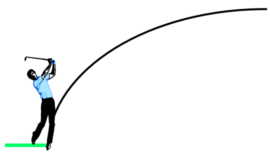
Calculate :
(a) the horizontal distance travelled by the satellite
(b) the final vertical velocity of the satellite
(c) the height from which the satellite was launched.

5. An archer fires an arrow and aims to hit the centre of a target board 50 metres away. The arrow is launched with a horizontal velocity of 100 ms^{-1}, at the same height as the target centre.



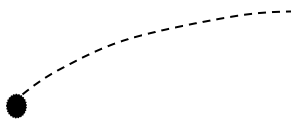
(a) How long does it take the arrow to hit the target?
(b) Calculate the final vertical velocity of the arrow.
(c) By how much does the arrow miss the centre of the target board?

6. A golfer strikes a golf ball and it follows a projectile path as shown below.



(a) What is the **vertical** velocity of the ball at its maximum height?
(b) What is the horizontal velocity of the ball if it takes 4 seconds to travel 400 metres?

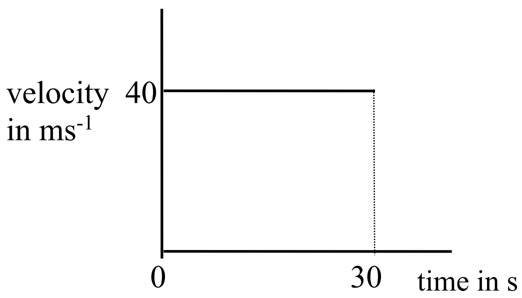
7. While on the Moon an astronaut throws a rock upwards and at an angle. The path of the rock is shown below.



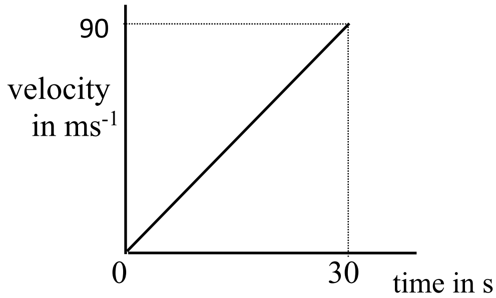
(a) What is the vertical velocity of the rock at its maximum height?
(b) How long does the rock take to reach its maximum height if it has an initial vertical velocity of 20 ms^{-1}?
(Remember! On the moon a = 1·6 ms^{-2})

8. Part of the space flight of a shuttle is represented in the velocity time graphs below.

Horizontal motion



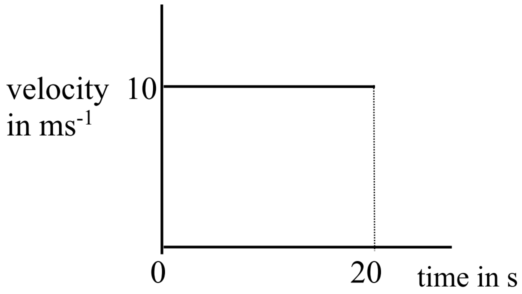
Vertical motion



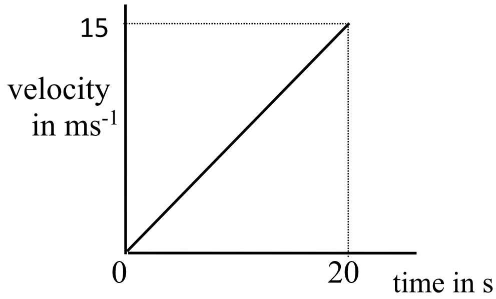
Use the graphs to find out how far the shuttle travels both horizontally and vertically in the 30 second journey.

9. During take off from Mars one of the boosters on a rocket fails causing the rocket to follow a projectile path rather than a vertical one.
The speed time graphs for a 20 second interval immediately after the booster failed are shown below.

Horizontal motion



Vertical motion



Use the graphs to calculate:
(a) the horizontal distance travelled during take off
(b) the acceleration in the vertical direction during the first 20 seconds
(c) the vertical distance travelled.

10. A stunt motor cyclist tries to beat the record for riding over double decker buses. He leaves the start position with a horizontal velocity of 35 ms^{-1} and lands 2·4 seconds later.

Calculate :
(a) the horizontal distance travelled by the cyclist
(b) the final vertical velocity of the motor cycle as it touches the ground
(c) the height of the platform.

Satellites

National 4 and National 5

In this section you can use the two equations which you have met previously in the "Waves and Radiation" unit:

$$v = f\lambda \qquad v = \frac{d}{t}$$

Where **v** = average wave speed in metres per second (m/s or ms^{-1})
f = frequency in hertz (Hz)
λ = wavelength in metres (m)
d = distance in metres (m)
t = time in seconds (s)

Helpful Hint
Radio waves, television waves and microwaves are all electromagnetic waves which travel at a speed of 3×10^8 m/s (3 00 000 000 ms^{-1}) through space.

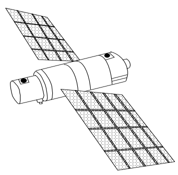
1. To communicate with satellites high above the Earth, microwaves are used. Microwaves are electromagnetic waves with very high frequencies, usually measured in giga hertz (GHz). Convert each of the following microwave frequencies into hertz.

   (a) 4 GHz (b) 11 GHz (c) 14 GHz (d) 6·5 GHz

2. A telecommunication satellite is in an orbit 20 000 **km** above the surface of the earth. A microwave of frequency 6 **G**Hz is used to send a signal from a ground station to the satellite. Calculate:

   (a) the wavelength of the microwave
   (b) how long it would take the signal to travel 20 000 km.

3. In 1964, SYNCOM, the world's first experimental geostationary satellite was launched into a 36 000 km orbit. A microwave of wavelength 2 cm could be used to communicate with the satellite in its geostationary orbit.



   (a) Calculate the frequency of microwaves which have a wavelength of 2 cm.
   (b) How long would it take a microwave to travel 36 000 km?

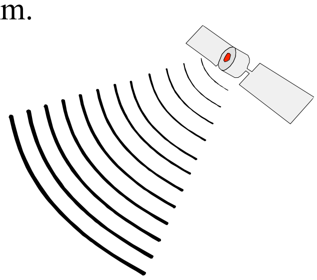
4. A dish aerial is used to transmit a 25 cm microwave signal to a spy satellite directly overhead.

(a) Calculate the frequency of the signal.
(b) How long will it take this signal to travel 20 000 km up to the satellite?

5. A dish aerial at a ground station collects a 12 GHz signal transmitted by a satellite. The signal took 0·15 s to reach the aerial.

(a) What is the wavelength of this signal?
(b) How far away is the satellite from the ground station?

6. In 1962 the communications satellite Telstar was used to relay the first live television pictures from the east coast of the U.S.A to Britain. Telstar orbited the earth at a height varying from 320 km to 480 km.



Calculate how long it would take for a 3 cm microwave signal to travel to the satellite if it was 320 km above the transmitter.

7. One of the first explorer satellites had an orbit height of 4 000 km above the surface of the Earth. Another satellite, Early bird, had an orbit height of 36 000 km. Which satellite took longer to make one complete orbit of the Earth?

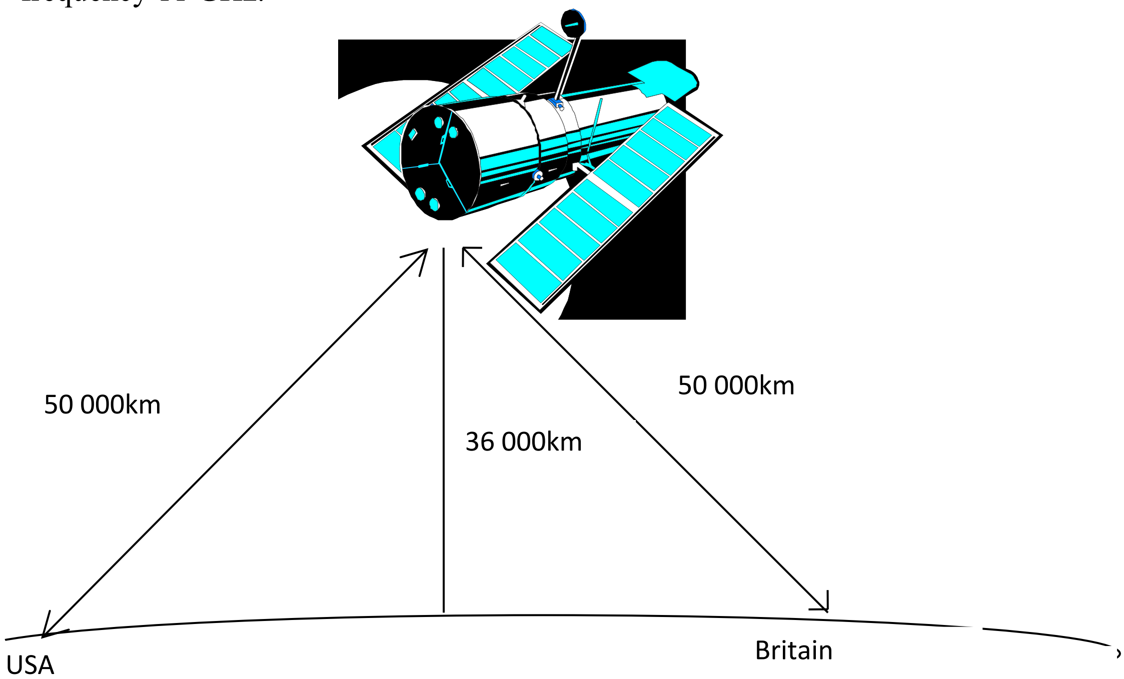
8. The communications satellite INTELSAT V was launched into a geostationary orbit in 1980. It could handle 12 000 telephone calls plus two TV channels at the same time using microwave frequencies of 4 GHz , 6 GHz, 11 GHz and 14 GHz.

(a) How long did INTELSAT V take to make one complete orbit of the Earth?
(b) Calculate the longest wavelength of signal used to communicate with the satellite.

9. A satellite in a geostationary orbit 36 000 km above the surface of the Earth receives a 3 cm microwave signal from the ground station. A second microwave signal with the same wavelength is sent to a satellite in a much lower orbit.

(a) Calculate the frequency of the 3 cm signal.
(b) It takes 0.05 seconds for the signal to reach the lower satellite.
Calculate the orbit height of this satellite.

10. A satellite is used to send a TV signal from Britain to the USA. The TV signal from Britain is sent to the satellite on a microwave carrier wave of frequency 14 GHz. At the satellite the signal is amplified and relayed to the USA on a carrier wave of frequency 11 GHz.



(a) Calculate the wavelength of the wave transmitted from Britain to the satellite.
(b) Calculate how long it takes the signal to travel from Britain to the satellite.
(c) What is the wavelength of the signal sent from the satellite to the USA?
(d) How long will it take for the TV signal to reach the USA from Britain?
(Assume that the time taken to amplify the signal at the satellite before relaying it is so small that it can be ignored.)

Work Done

National 5

In this section you can use the equation:

work done = force x distance

also written as

$$E_w = F d$$

where E_w = work done in joules (J)
F = force in newtons (N)
d = distance in metres (m).

1. Find the missing values in the following table.

	Force (N)	*Distance* (m)	*Work Done* (J)
(a)	150	25	
(b)	6 500	320	
(c)		52	6 500
(d)	2		542

2. A gardener pushes a wheelbarrow with a force of 250 N over a distance of 20 m. Calculate how much work he does.

3. Fiona pushes a pram with a force of 150 N. If she does 30 000 J of work calculate how far she pushes the pram.

4. Joseph pulls his sledge to the top of a hill. He does 1 500 joules of work and pulls the sledge a distance of 50 metres. With what force does he pull the sledge?

5. A horse pulls a cart 3000 m along a road. The horse does 400 000J of work. What force does the horse exert on the cart?

6. A car tows a caravan with a constant force of 2 500 N over part of its journey. If the car does 8 500 000 J of work calculate how far it pulls the caravan.

7. During a race a motorcycle engine produced a steady forward force of 130 N. Calculate the work done by the engine if the motorcycle covered a distance of 50 000m.

8. A motor boat tows a yacht out of a harbour. If the motor boat exerted a force of 110 000N and did 200 000 000 J of work calculate how far it towed the yacht.

9. A locomotive exerts a force of 15 **k**N on a train of carriages. The locomotive pulls the train over a distance of 5 **k**m. Calculate the work done by the locomotive.

10. On an expedition to the North Pole, Husky dogs were used to pull the sledges carrying supplies for the journey. One team of dogs did 650 **M**J of work during the 1 500 **k**m journey.

    (a) Calculate the average force that the team of dogs exerted on the sledge.
    (b) There are 8 dogs in a team. Calculate the average force exerted by each dog during the journey.

11. How far can a milk float travel if the electric engine produces a steady force of 2 **k**N and does 9 500 **k**J of work before the battery needs recharged?

12. Peter and John work at a supermarket. They are responsible for collecting trolleys from the trolley parks in the car park and returning them to the store.

    (a) Peter collects trolleys from the furthest trolley park. He has to pull them 150 m back to the store and collects 10 trolleys at a time. If Peter pulls the 10 trolleys together with an average force of 350 N calculate how much work he does in one journey.

    (b) John does not have so far to walk so he collects 20 trolleys at a time. He pulls his trolleys with an average force of 525 N and covers 100 m each journey. Calculate how much work he does in one trip.

    (c) Each boy has to return 80 trolleys to the store before finishing their shift.
        (i) Calculate how many journeys each boy has to make.
        (ii) Show by calculation who does the most work.

Helpful Hint
Special case
When work is done **lifting** an object at a steady speed, the force required is equal to the **weight** of the object .

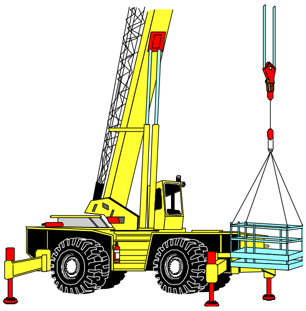
So … **Work done = weight x height**

13. A painter is painting the ceiling of a room. She fills her tray with paint and lifts it up the ladder. The weight of the full paint tray is 30 newtons and she lifts it through a height of 2 m. Calculate the amount of work she does.

14. Marco climbs a rope in the school gym during his P.E. lesson. He weighs 600 N and climbs 8 m up the rope at a steady speed. Calculate how much work he does.

15. A chair lift carries two skiers and their equipment to the top of a ski run which is at a height of 300 m. The chair lift weighs 500 N and the skiers with their equipment weigh 1 800 N. Calculate the work done by the chair lift motor in lifting the skiers to the top of the ski run.

16. A crane lifts a concrete block through a height of 40 m. The crane does 650 kJ of work.



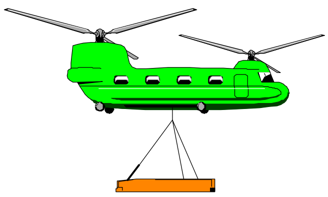
Calculate:

(a) the weight of the concrete block
(b) the mass of the concrete block.

17. A librarian is placing books on to the fiction shelf which is 2 metres from the ground. He does 80 joules of work lifting the books from the floor to the shelf.

(a) Calculate the weight of the books.
(b) What is the mass of the books?
(c) If each book has an average mass of 400 g calculate how many books the librarian places on the shelf.

18. A search and rescue helicopter is called to a ship in the North Sea to airlift an injured sailor to hospital. The helicopter lifts the sailor 150 m at a constant speed of 4 m/s . The sailor has a mass of 75 kg.



Calculate
(a) the weight of the sailor
(b) the work done by the helicopter during this lifting operation.

Potential Energy

In this section you can use the equation:

potential energy = mass x gravitational field strength x height

also written as

$$E_p = m\,g\,h$$

where

E_p = potential energy in Joules (J)
m = mass in kilograms (kg)
g = gravitational field strength in newtons per kilogram (Nkg^{-1})
h = height in metres (m).

1. Find the missing values in the following table.

	Mass **(kg)**	***Gravitational Field Strength*** **(Nkg^{-1})**	***Height*** **(m)**	***Potential Energy*** **(J)**
(a)	25	9.8	15	
(b)	30	9.8	45	
(c)	35	9.8		450
(d)	2	9.8		70
(e)		9.8	5	120
(f)		9.8	57	6000

2. Calculate the gravitational potential energy gained when:
   (a) a crate of mass 20 kg is lifted up 12 m
   (b) an injured climber of mass 75 kg is raised through a height of 200 m
   (c) a pile of bricks of mass 15 kg is hoisted up 25 m.

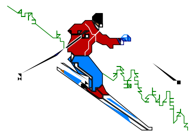
3. Calculate the mass of a loaded crate which:
   (a) gains 200 J of gravitational potential energy when lifted up 15 m
   (b) loses 2 000 J of gravitational potential energy when dropped 26 m
   (c) loses 1 500 J of gravitational potential energy when dropped 8 m.

4. Calculate the height climbed by a 60 kg window cleaner if he gains 1 800 J of gravitational potential energy by climbing up his ladder.

5. A pot holer of weight 70 kg climbs 60 m. How much potential energy does he gain?

6. A car containing 4 passengers has a total mass of 1 200 kg. How much potential energy does it lose as it travels down a 40 m high slope?

7. Calculate the mass of a skier if he loses 78 000 J of potential energy when skiing down a slope of 120 m.



8. Calculate the potential energy gained by a ping pong ball lifted to a height of 2m if it has a mass of 30 **g**.

9. Water in the reservoir of a hydroelectric power station 'holds' 120 **MJ** of potential energy. The mass of water is 120 tonnes (**1 tonne = 1 000 kg**).
Calculate the height of the stored water.

10. A mountain rescuer is trying to rescue a group of climbers stranded on a ledge 250 m above ground level. The only way to reach the climbers is to climb down to them from another ledge 440 m above ground level. If the mountain rescuer has a mass of 85 kg calculate:

(a) the potential energy gained initially by climbing to the higher ledge
(b) the amount of potential energy he **loses** as he climbs to the lower ledge.

<u>Helpful Hint</u>

If a question gives you the weight of an object and asks you to calculate the potential energy, you can use

$$\mathbf{E_p = (mg) \times height}$$

$$\mathbf{E_p = weight \times height} \quad \text{(Since weight = mg)}$$

11. Calculate the potential energy lost by a person of weight 500 N who jumps from a wall 2 m high.

12. Calculate the potential energy lost by a lift which descends through 50 metres. The total weight of lift plus passengers is 10 800 N.

13. During a sponsored 'stretcher lift' a group of students lift a stretcher plus patient 120 metres up a hill. If the total weight of the patient and the stretcher is 1 000 N, calculate the amount of potential energy they gain.

14. Calculate the maximum height of a fun ride in which the passengers lose 8 500 J of energy as their carriage drops through the maximum height. The passengers and the carriage have a combined weight of 400 N

15. Calculate the weight of a pile of bricks if they gain 2 000 J of energy as they are lifted up 20 metres.

Kinetic Energy

In this section you can use the equation:

$$\textbf{kinetic energy} = \frac{1}{2} \times \textbf{mass} \times \textbf{velocity}^2$$

also written as

$$E_k = \frac{1}{2} m v^2$$

where E_k = kinetic energy in joules (J)
m = mass in kilograms (kg)
v = velocity in metres per second (ms^{-1}).

1. Find the missing values in the following table.

	Mass **(kg)**	***Velocity*** **(ms^{-1})**	***Kinetic energy*** **(J)**
(a)	2·0	3·0	
(b)	0·5	15·0	
(c)	4·5	4·0	
(d)	4·0	5·0	
(e)	0·24	10·0	
(f)	20·0	200·0	

2. Calculate the kinetic energy of a car travelling at 15 ms^{-1} if the car has a mass of 1 200 kg.

3. A ball, which has a mass of 0·5 kg, rolls down a hill. What is its kinetic energy at the foot of the hill if its velocity is 3 ms^{-1} ?

4. A mass of 2 kg falls from a table and has a velocity of 4·4 ms^{-1} just before it hits the ground. How much kinetic energy does it have at this point?

5. A bus, travelling at a constant velocity of 10 ms^{-1}, accelerated to 24 ms^{-1}. If the bus had a mass of 5 000 kg, calculate :
   (a) the kinetic energy of the bus before it accelerated
   (b) the kinetic energy of the bus at its new velocity.

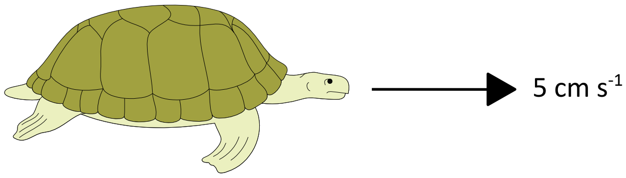
6. A long distance runner has a mass of 70 kg. If he crosses the finishing line with a velocity of 5·4 ms^{-1}, how much kinetic energy does he have at the finishing line?

7. The mass of an electron is $9{\cdot}11 \times 10^{-31}$ kg. What is the kinetic energy of an electron which is travelling with a velocity of 2×10^{7} ms^{-1}?

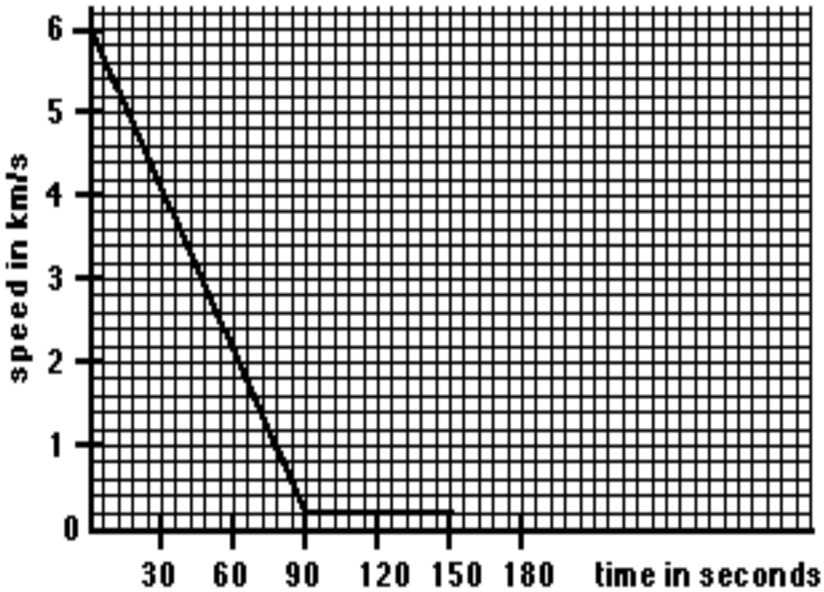
8. A 50 000 kg train is travelling at 72 **kmh^{-1}**.
(72 km = 72 000 m, 1 hour = 3600 s)

(a) What is its velocity in ms^{-1}?
(b) How much kinetic energy does the train have?

9. A tortoise is moving along the ground with a velocity of 5 **cm s^{-1}**. If its mass is 3 kg, how much kinetic energy does it have?



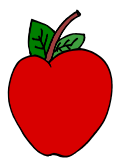
10. The graph below shows how the velocity, in **km s^{-1}**, of a space capsule decreased as the capsule re-entered the Earth's atmosphere.



If the space capsule had a mass of 4 500 kg, how much kinetic energy did it **lose** as it re-entered the Earth's atmosphere?

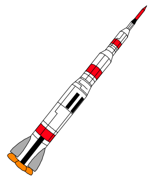
11. What is the velocity of a ball which has 114 J of kinetic energy and a mass of 2·28 kg?

12. Find the mass of an apple given that the apple is rolling along a table at 0·8 ms^{-1} and has 0·04 J of kinetic energy.



13. Calculate the velocity of a taxi which has a mass of 1500 kg and 363 **kJ** of kinetic energy.

14.



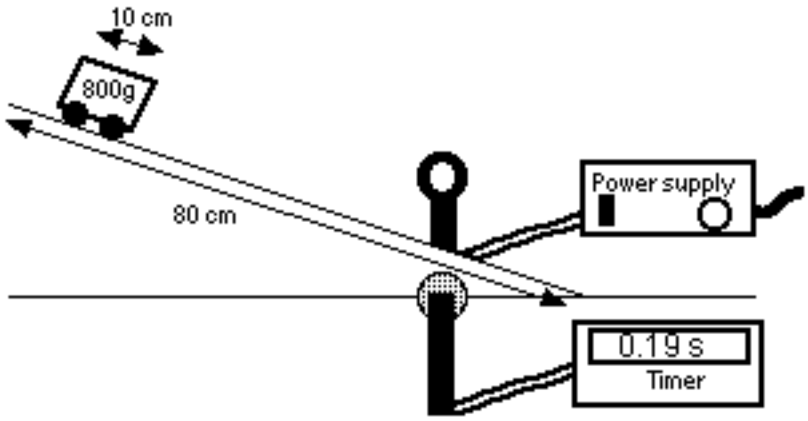
A space capsule travelling at 5 **km s^{-1}** has 6×10^{10}J of kinetic energy.

(a) What is the velocity of the capsule in ms^{-1}?
(b) What is the mass of the capsule?

15. A motor cycle and a 5 000 kg bus have equal amounts of kinetic energy . The motor cycle is travelling at 35 ms^{-1} and has a mass, including rider, of 370 kg.

(a) How much kinetic energy does the motorcycle have?
(b) Calculate the velocity of the bus.

16. A trolley rolls down a ramp which is 80 cm long. It passes through a light gate near the bottom of the ramp and the timer records a time of 0·19 s for the trolley to cut the light beam.



The mass of the trolley is 800 **g** and it has a length of 10 **cm**.

(a) What is the speed of the trolley as it passes through the light gate?
(b) How much kinetic energy does it have as it passes through the light gate?

17. A hospital lift has a mass of 800 kg when empty. On one occasion the lift, carrying passengers, rises with a speed of 1·5 ms^{-1} and has 1 215 J of kinetic energy.
How many people were in the lift on this occasion?
(Assume that each person has a mass of 70 kg)

18. A minibus of mass 2 800 kg was travelling with a speed of 10 ms^{-1}. It then accelerated at a rate of 0·8 ms^{-2} for 10 seconds.

(a) What was the kinetic energy of the minibus while it was travelling at 10 ms^{-1}?
(b) What was the speed of the minibus after 10 seconds of acceleration? (**uvat!**)
(c) How much kinetic energy did the minibus gain during the acceleration period?

Conservation of Energy – Extension Calculations

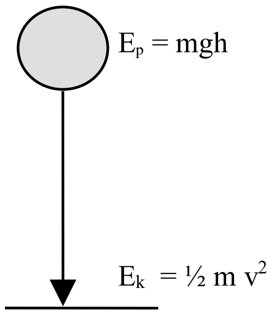
National 5

Helpful Hint

When an object falls its potential energy is converted to kinetic energy (assuming air resistance is negligible).

i.e. $E_p \rightarrow E_k$

We can use this principle of **conservation of energy** to solve many problems.
e.g. a ball (mass m) falling through a height, h.



Finding the **landing velocity** of a falling object.

$$E_p = E_k$$
$$mgh = \frac{1}{2} mv^2$$

So, rearranging this:

$$\mathbf{v = \sqrt{(2gh)}}$$

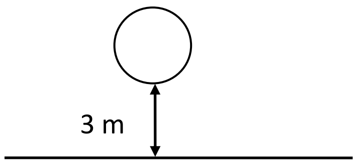
Finding the **height** through which an object falls.

$$E_k = E_p$$
$$\frac{1}{2} mv^2 = mgh$$

So, rearranging this:

$$\mathbf{h = \frac{v^2}{2g}}$$

1.



A 2 kg ball falls through 3 m to land on Earth.

(a) How much potential energy does it lose during its fall?

(b) How much kinetic energy does it gain during its fall, assuming that there is no air resistance?

(c) Calculate the maximum speed of the ball as it hits the ground.

2. A spanner falls from a desk which is 0·8 m high. If the spanner has a mass of 0.5 kg, calculate :

(a) the potential energy lost by the spanner as it falls

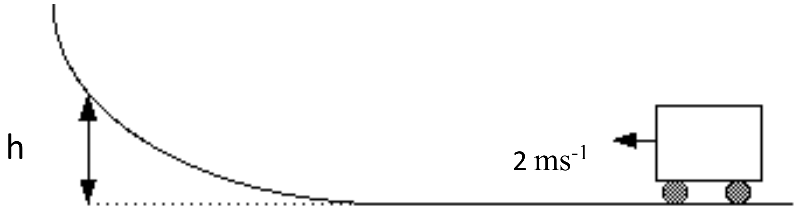
(b) the kinetic energy gained by the spanner as it falls, assuming negligible air resistance.

(c) the speed of the spanner just as it hits the ground.

3. A pencil case has a mass of 0.2 kg and is dropped from a height of 0·45 m.

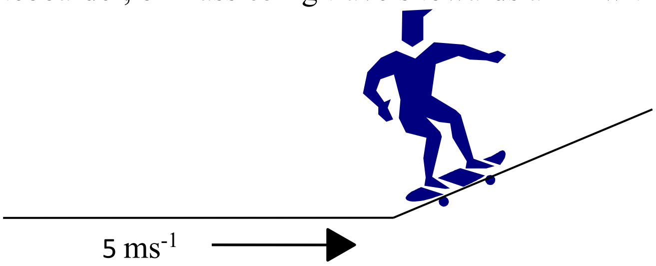
(a) How much potential energy does the pencil case lose as it falls to the ground?
(b) What is the kinetic energy of the pencil case as it hits the ground?
(c) With what speed does the pencil case hit the ground?

4. A trolley rolls towards a ramp with a speed of 2 ms^{-1}. The trolley has a mass of 0·3 kg.



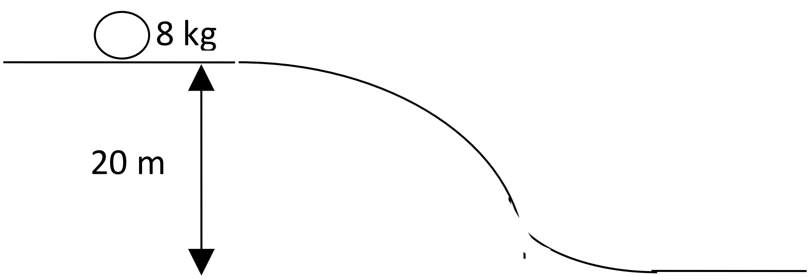
(a) Calculate the kinetic energy of the trolley before it goes up the ramp.
(b) If there are no energy losses due to friction how much potential energy does the trolley gain as it goes up the ramp?
(c) What height does the trolley reach on the ramp?

5. A skateboarder, of mass 65 kg travels towards a hill with a speed of 5 ms^{-1}.



(a) What is the kinetic energy of the skateboarder as he travels towards the hill?
(b) If there are no energy losses due to friction, how much potential energy will the skateboarder gain on the hill?
(c) What height will the skateboarder reach on the hill?

6. An 8 kg boulder rolls down a hill as shown below.



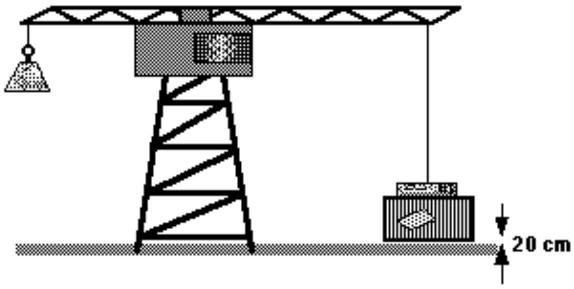
(a) How much potential energy does the boulder lose as it rolls down the hill?
(b) Calculate the speed of the boulder at the bottom of the hill, assuming that no energy is lost due to friction?

7. A diver, who has a mass of 70 kg, dives from a cliff top into the sea. The cliff top is 11·25 m above the water surface. At what speed does the diver enter the water, assuming that frictional effects are negligible?

8. A box is released from a helicopter which is hovering 10 m above the ground. Calculate the speed of the box as it strikes the ground, assuming that frictional effects are negligible.

9. A twenty pence piece falls from the top of a skyscraper and lands, on the street below, with a speed of 80 ms^{-1}. How tall is the skyscraper? (Assume that there is no air resistance.)

10. A crate is released from a crane while it is hanging 20 **cm** above the ground.



With what speed does the crate land on the ground?

11. An advertising company produces a stunt where a girl on horseback jumps across a gap between two buildings. The combined mass of horse and rider is 420 kg and they are galloping with a speed of 28 ms^{-1} as they leave the first building.
The roof of the second building is 1 m below the roof of the first one.

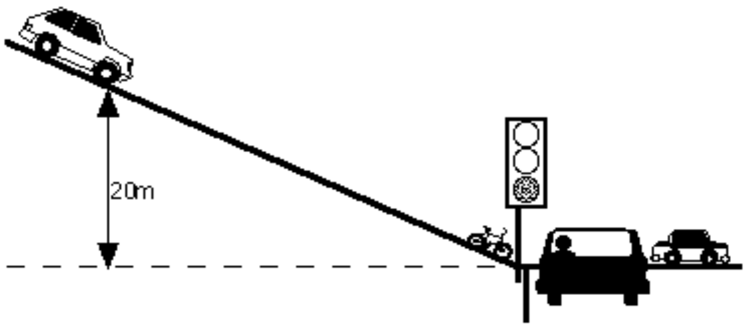
(a) Calculate the kinetic energy of the horse and rider as they leave the first building.
(b) How much gravitational potential energy do the horse and rider lose during the stunt?
(c) Assuming that there are no energy losses due to air resistance, what is the total amount of kinetic energy of the horse and rider as they land on the second building?
(d) With what speed do the horse and rider land on the second building?

12. If a bullet is fired vertically upwards, with a speed of 150 ms^{-1}, what is the maximum height it could reach if frictional effects are negligible.

13. A skateboarder moves towards a slope with a constant speed of 8 ms^{-1}. Her mass, including her skateboard, is 60 kg and she reaches a height of 2·5 m on the slope.
The slope has a rough surface so frictional forces help to slow her down.

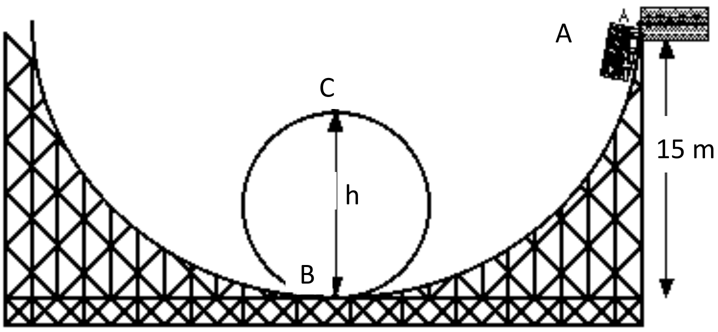
(a) How much kinetic energy did she have at the foot of the slope?
(b) What happened to her kinetic energy as she moved up the slope?
(c) How much potential energy did she gain on the slope?
(d) How much work was done against friction on the slope?

14. A car, of mass 1 500 kg, is parked on a hill at a height of 20 m. The brakes fail and the car begins to roll towards a busy junction at the foot of the hill. The car reaches the junction with a speed of 18 ms^{-1}.
(Friction between the road and the tyres is important here.)



(a) Calculate the amount of potential energy lost by the car as it rolled down the hill.
(b) How much kinetic energy did the car have at the junction?
(c) How much energy was 'lost' due to friction as the car rolled down the hill?

15. A typical loop-the-loop rollercoaster in a fun park is shown below :



During one ride the total mass of carriage and passengers was 3 000 kg.

When all passengers were locked in place the carriage was pulled up the track to the start point A. This was at a height of 15 m.

The carriage was then released and it sped down the track past point B and round the loop. By the time it had reached the top of the loop, point C, it had lost 6 000 J of energy due to friction and was travelling at 8 ms^{-1}.

(a) How much potential energy did the carriage lose in going from A to B?
(b) How much kinetic energy did the carriage have at the top of the loop?
(c) How much potential energy did the carriage regain in moving from B up to C?
(d) Calculate the height of the loop

Energy Transformations

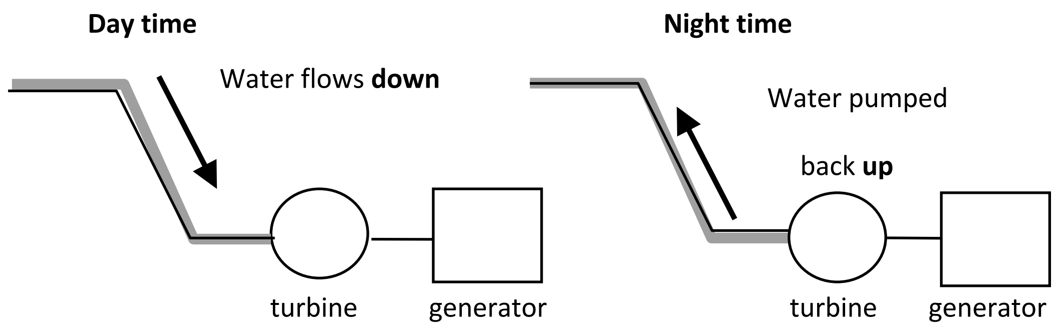
In this section you can use the following equations:

$$E = Pt \qquad P = IV \qquad E_p = mgh$$

where	**E**	=	energy in joules(J)
	I	=	current in amps (A)
	t	=	time in seconds(s)
	E_p	=	gravitational potential energy in joules(J)
	m	=	mass in kilograms(kg)
	g	=	gravitational field strength in newtons per kilogram(N /kg)
	h	=	height in metres(m)
	P	=	power in watts(W)
	V	=	voltage in volts (V)

Helpful Hint

Energy cannot be created or destroyed only changed from one form to another. In a pumped storage hydroelectric power station, the potential energy of the water is converted to electrical energy when it **falls** from the reservoir into the turbines attached to the generator. At night when the water is pumped back **up** to the reservoir electrical energy in the pump is converted into potential energy of the water.



Potential energy → Electrical energy

Electrical energy → Potential energy

Often in these questions you will be given the **rate** of flow of water i.e. how many kilograms flow each second. This gives you **two** pieces of information, **mass** and **time**.

1. How much potential energy could be converted into electrical energy when 200 kg of water falls 40 m into a turbine attached to a generator?

2. How much energy is stored in a pumped storage hydroelectric scheme if 6 000 kg of water is pumped up 210 m to a reservoir at night time when there is a surplus of electricity?

3. In a hydroelectric power station 400 kg of water flow each second through the turbines of the power station from a loch 200 m above the turbines.

   (*a*) How much potential energy is lost by the water each second?

   (*b*) How much electrical energy could be generated each second assuming that there are no energy losses?

   (*c*) What would the output power of this station be?

4. A small reservoir is situated 120 m above a hydroelectric power station. The station gives an output power of 2·25 MW.

   (*a*) How much electrical energy is generated each second in this power station?

   (*b*) How much potential energy must the water flowing into the turbines lose each second in order to generate this electricity?

   (*c*) What mass of water must flow each second through the turbines of the power station in order to generate 2·25 MW of electricity?

5. The generator of a hydroelectric power station produces an output power of 1·1 MW. Water flows at a rate of 300 kg per second from the loch above the power station.

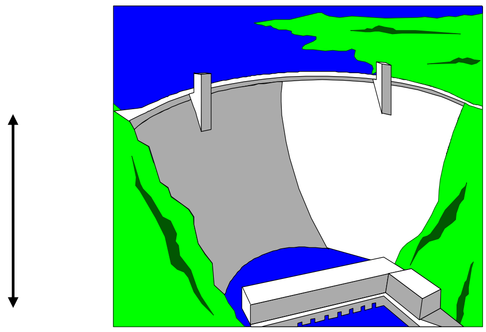
(*a*) How much electrical energy is generated each second?

(*b*) How much potential energy must be converted into electrical energy each second?

(*c*) How high is this loch?

6. (*a*) How much energy is stored in the reservoir of this hydroelectric scheme if it contains 200 000 kg of water?

water falls through
a height of 150 m



(*b*) If all this water flows into the turbines attached to the generators in

1 hour what would the output power from this station be?

7. 2·4 x 10^6 kg of water flow from a loch 150 m high in 8 hours. What power could this water generate in a hydroelectric power station?

8. An electric pump is required to fill a reservoir with $1{\cdot}6 \times 10^6$ kg of water in 6 hours. The reservoir is 40 m above the pump house.

(*a*) How much potential energy must the water gain in 6 hours?

(*b*) How much electrical energy must the pump receive in the 6 hours?

(*c*) Calculate the power of the pump.

9. In a model pumped storage hydroelectric power station an electric pump is used to lift water through a height of 1 m. The pump is connected to a 12 V supply and draws a current of 2 A.

(*a*) How much electrical energy does the pump use each second?

(*b*) How much potential energy could this pump give to the water each second?

(*c*) What mass of water can the pump lift each second?

10. A 230 V pump drawing a current of 3 A is required to lift 200 kg of water through a height of 7 m .

(*a*) How much potential energy will the water gain?

(*b*) How much electrical energy must be provided to the pump?

(*c*) How long will it take for the pump to lift all the water?

The Observable Universe

National 4 and National 5

1. Read the following clues and select the answer from this list. Some answers can be used more than once.

star	**moon**	**planet**	**solar-system**
universe	**exo-planet**	**galaxy**	**light year**

(a) The distance light travels in one year.
(b) A ball of gases continually reacting to give out heat and light.
(c) This orbits a star.
(d) Our Sun and its 8 planets.
(e) Everything?
(f) A large group of stars.
(g) A natural satellite of Earth.
(h) The Sun is one of these.
(i) The Milky Way is one of these.
(j) This orbits a star outside our solar system.

2. How can Scientists detect exo planets?

3. A planet would need to meet several requirements in order to sustain life as we know it. Some suggestions are written below. Write down TRUE or FALSE for each one.

(a) The planet must be not too big and not too small.
(b) The planet must already have intelligent life on it.
(c) The planet surface must be liquid and gas.
(d) The planet must be in orbit around a stable, long lived star.
(e) The planet must be very close to its star.
(f) The planet must have a protective electromagnetic field.

National 5

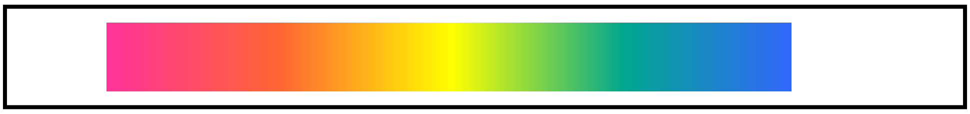
4. Scientists widely agree that all matter was once packed into a tiny space, then the Universe was created as a result of a massive explosion.
(a) What is the name of the theory that attempts to explain this origin of the Universe?
(b) By this theory, how long ago did this explosion happen?
(c) Nowadays, are our galaxies STABLE or STILL MOVING APART or MOVING CLOSER TOGETHER?
(d)

5. High frequency radiation like Ultraviolet, X-Rays and Gamma rays are given off by extreme astronomical events.
Give 2 examples of “extreme astronomical events” and explain what they are.

6. Identify the types of spectra shown in the following diagrams.

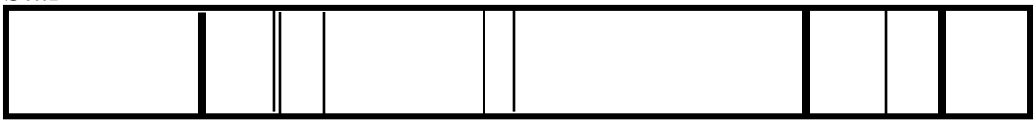
A

B



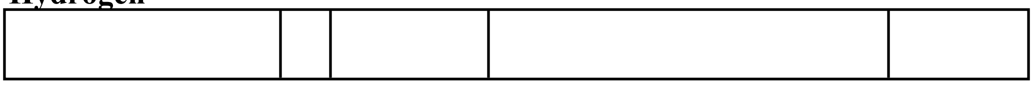
7. Spectral data from a distant star is shown below.

Star

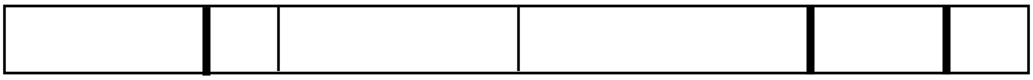


Known spectral data from various elements is as follows:

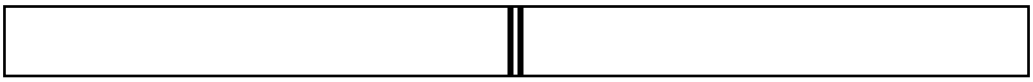
Hydrogen



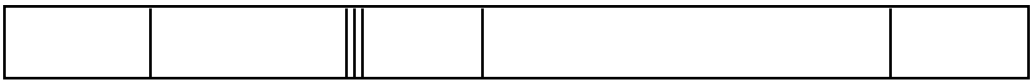
Helium



Sodium



Calcium



Identify the elements present in the star.

8. The temperature of a star can be estimated by the frequency / colour of light that it emits.

(a) Is the blue end of the spectrum the high or low frequency end?

Look at the following chart and use it to answer the questions below.

Spectral Type	Example(s)	Temperature Range	Key Absorption Line Features	Brightest Wavelength (color)
O	Stars of Orion's Belt	>30,000	Lines of ionized helium, weak hydrogen lines	<97 nm (ultraviolet)*
B	Rigel	30,000 K–10,000 K	Lines of neutral helium, moderate hydrogen lines	97–290 nm (ultraviolet)*
A	Sirius	10,000 K–7,500 K	Very strong hydrogen lines	290–390 nm (violet)*
F	Polaris	7,500 K–6,000 K	Moderate hydrogen lines, moderate lines of ionized calcium	390–480 nm (blue)*
G	Sun, Alpha Centauri A	6,000 K–5,000 K	Weak hydrogen lines, strong lines of ionized calcium	480–580 nm (yellow)
K	Arcturus	5,000 K–3,500 K	Lines of neutral and singly ionized metals, some molecules	580–830 nm (red)
M	Betelgeuse, Proxima Centauri	<3,500 K	Molecular lines strong	>830 nm (infrared)

*** All stars above 6,000 K look more or less white to the human eye because they emit plenty of radiation at all visible wavelengths.**

(b) Light from which end of the spectrum, blue or red, indicates a hotter star?

(c) Our nearest star is our Sun. Which spectral type is our Sun?

(d) Which 3 spectral types emit the strongest radiation outside of the visible spectrum?

(e) Where are some of the hottest stars?